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Ants' nesting activity as a factor of changes in soil physical properties

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Abstract. In the process of nesting activity ants change the physical characteristics of the soil. We studied penetration resistance of ants' nests, their temperature regime and particle size distribution for the nests of three soil-dwelling ants species (*Lasius niger*, *L. flavus* and *Formica cunicularia*). Control sites were located in different regions of Russia (Ryazan region and Arkhangelsk region) on different soils (post-agro-sod-podzol gley sandy loam on alluvial-deluvial sediments in Ryazan region and developed sod-podzolic, light loamy soil on the moraine in Arkhangelsk region). So we found out that ants can reduce the penetration resistance of the soil by 8 times compared to the control (66 kPa in control soil and 7,8 kPa in ants nests). The temperature regime of anthills is more aligned and the average temperature of ants nest was lower than in the control (21,4 ^{0}C in the control soil mound and from 20,8 ^{0}C to 17,7 ^{0}C in ants nests depending on their species). The particle size distribution, by contrast, was more variable compared to the control.

1. Introduction

Ants are the most numerous group of insects in Central Russia. Many species of ants inhabit the surface layer of biocenoses where large nests are formed, which are located both on the soil surface and in the soil column. In this regard, from the point of view of soil science many species of ants that are not formally related to pedobionts should be considered as soil animals. Indeed, according to some estimates ants for example *Lasius niger* and *L. flavus* in the process of nesting can process from 26 m^3 to 50 m^3 of soil per 1 ha, and the total volume of ant nests in a small area of meadows can reach 270 m^3 [1, 2]. The nature of the impact of ants on the soil properties is multifarious: this is pedoturbation [3, 4], and enrichment of the soil with nutrients, and the peculiar way of their distribution in the ant nest with depth a different morphology of the soil profile inside the ant nest and a number of other indicators [5, 6]. Simultaneously, for example the dynamics of some microbiological processes occurring in an ant nest differs from the dynamics of these same processes measured in the control, non-ants-dwelled intact soil, and apparently, is related to the activity of ants during the growing season [7].

This paper presents the results of the determination of some physical indicators of anthill soils. The goal of the study was to show differences in the temperature regime of ant nests, to determine the resistance of the penetration values of anthills and control soils, to study the particle size distribution of ant nests compared to control soils.

2. Objects and methods

In this study, the nests of ants *Lasius niger*, *L. flavus* and *Formica cunicularia* were investigated. In the nests located on the fallow field on the high bank of the river Unzha in the Ryazan region we determined the value of penetration resistance using a manual penetrometer EIJKELKAMP. At the same site, we studied the temperature regime of anthills using loggers produced by Dallas industries. To this end, at the beginning of the growing season, in May, a logger was placed in an anthill at the level of the soil surface, and a soil mound similar in volume to an anthill was placed near the anthill, under which the logger was also placed as a control measurement. Loggers recorded data every 2 hours, and at the end of the growing season (second half of September) loggers were extracted to read the recorded information. The control soil is post-agro-sod-podzol gleyate sandy loam on alluvial-deluvial sediments according to the soil classification of 1977 [8] or developed sandy-sandy sod-podzolic soil [9]. According to the international classification (WRB), this soil can be classified as humid arenosols.

The determination of the granulometric composition was carried out in samples of ant nests of the *L. niger* selected on different elements of the relief of the valley of the river Veryuga in the Ustyansky district of the Arkhangelsk region at the point with coordinates 61^{0}41'25.0" N 43^{0}50'18.0" E. The determination of the particle size distribution was also carried out in samples of the organogenic horizon of the control soil — developed sod-podzolic, light loamy on the moraine or in accordance with the WRB classification - Dystric Retisol (Loamic Abrubtic). The granulometric composition was determined by laser diffraction using an Analysette 22 comfort instrument (Fritsch, Germany). The samples were dispersed using ultrasonic treatment on a Digital Sonifir 250 instrument (Branson Ultrasonics, USA) at a given power (40% W). For analysis, the soil was ground in a mortar with a pestle with a rubber tip then sieved through a 1 mm sieve, the weight of the sample was 300-400 mg [10, 11].

3. Results and discussion

Figure 1 presents the averaged results of measuring the penetration resistance of the control soil in comparison with anthills inhabited by ants *L. niger* and *L. flavus*. From the obtained results, it follows, firstly, that the penetration resistance of the soil itself in selected areas is quite variable, on average, equal to 37,2 kPa in the vicinity of the *L. flavus* nests and 13,7 kPa in the control soil of *L. niger*, i.e. soil hardness in the vicinity of *L. flavus* nests is approximately 2 times higher. The average soil hardness of the *L. flavus* nest in a 50 cm thick layer is 3.7 kPa against 9.3 kPa in *L. niger* nests. Thus, it is obvious that the ants of *L. flavus* in the process of nesting can reduce soil hardness more significantly.

This is especially noticeable at a depth of 40 cm, apparently, in the layer of the plough-pan, where the penetration resistance force of the intact soil is maximum (about 66 kPa), while in ants nests, it averages 7.8 kPa, i.e. almost 8 times lower. This is probably due to the ecology of ants of this species. It is known that among ants of the genus *Lasius*, the species *L. flavus* is considered to be truly pedobiont; these ants can live in the soil permanently, appearing on the surface only during the breeding season.

Later, temperature conditions were determined in the nests of the ants *L. niger*, *L. flavus* and *F. cunicularia* (figure 2). From the data obtained, it follows that the average temperature on the soil surface was 21.5 C^0 (min 11.9 C^0 max 30.1 C^0 $\Delta = 18.4$ C^0), in the control - the soil mound, at the base of which a logger was placed 21.4 C^0 (min 11.4 C^0 max 26.2 C^0 $\Delta = 14.8$ C^0), at the base of *L. niger* anthill 20.8 C^0 (min 11.3 C^0 max 27.5 C^0 $\Delta = 16.2$ C^0), at the base of the anthill of *F. cunicularia* nest 19.6 C^0 (min 11.3 C^0 max 24.8 C^0 $\Delta = 13.5$ C^0), at the base of the nest hill of *L. flavus* 17.7 C^0 (min 10.2 C^0 max 23.2 C^0 $\Delta = 13.7$ C^0). Thus, the smallest temperature difference is observed in the nests of ants, which may indicate the ability to control the temperature in anthills. Generally, the ability of ants to maintain a certain temperature in the nest is known and is achieved by regulating the moisture regime or by changing the nest ventilation mode, for which the ants are able, for example, to open additional "ventilation holes" [12].

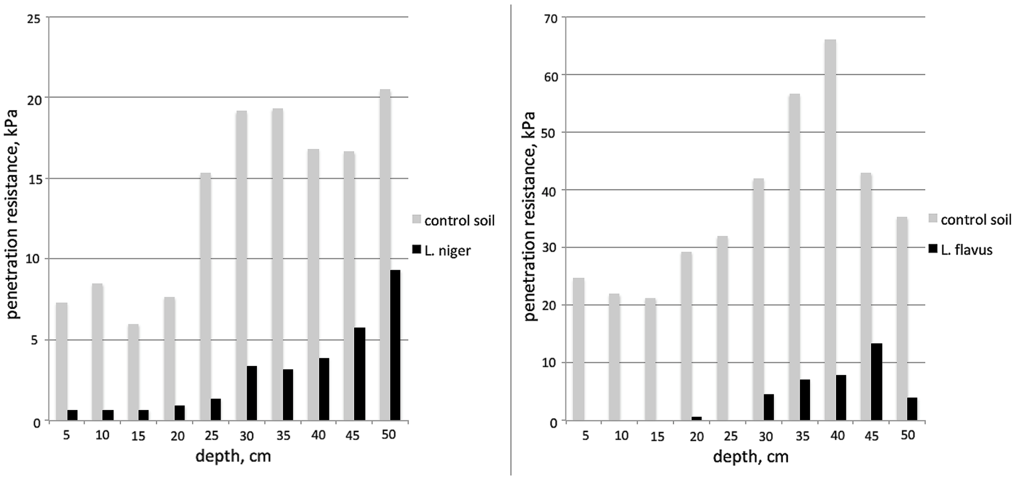

Figure 1. The penetration resistance (Pa) of the control soil and ant nests *L. flavus* (right) and *L. niger* (left).

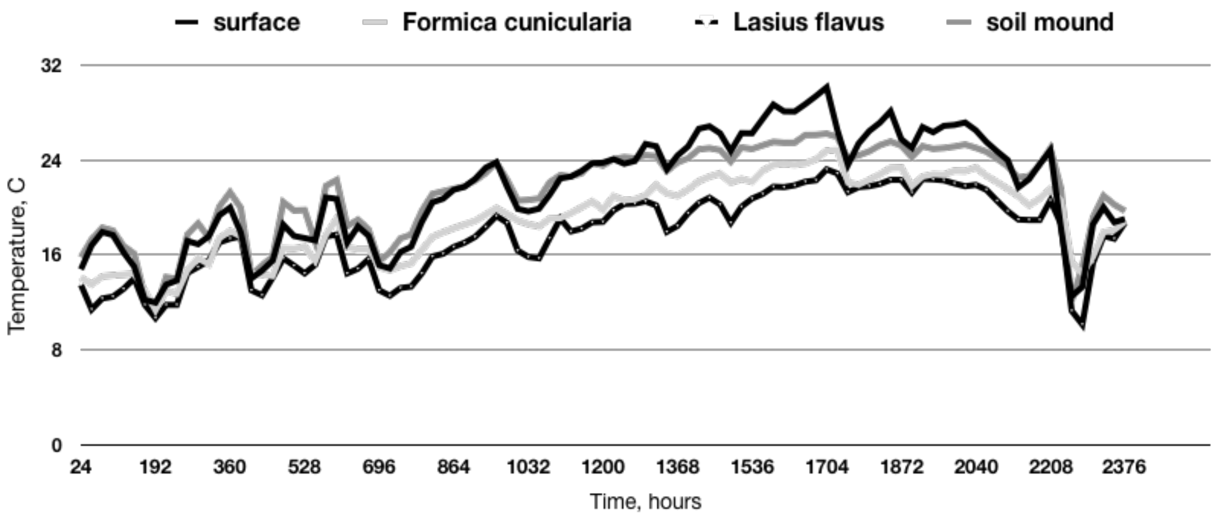

Figure 2. Temperature regime of the nests of *Formica cunicularia, Lasius niger* and *Lasius flavus***.**

On the other hand, it is known that ants building earthen mounds are less able to regulate their temperature conditions as compared with ants building complex nests. It can be assumed that the optimum temperature inside the earthen anthill is established due to the gradient of its humidity and the ambient temperature. Thus, naturally, ants - pedobionts *L. flavus* live in the most thermostatically controlled nest with the lowest average temperature at the base of the anthill. And the opportunistic species *L. niger* nest is less thermostatically controlled and, in terms of temperature regime, is similar to the control artificial soil mound.

A comparative study of the temperature regime of ant nests in the field is a complicated procedure. The result of the measurements is influenced by many factors. Moreover, it is difficult to carry out correct control measurements. We do not consider the proposed method to be optimal, since it is almost impossible to create a control earthen mound identical to an anthill. We believe that the study of the influence of ants on the temperature regime of nests can be more accurately studied in controlled laboratory conditions. In another study, the granulometric composition of *L. niger* nests was studied on different elements of the Veryuga valley relief in the Ustyansky district of the Arkhangelsk region. The granulometric composition was studied in samples of anthill and samples of organogenic horizons of control soils.

Samples of ant nests selected on the floodplain were identified as light loamy. Their distinguishing feature is the low content of the fine sand fraction (50–250 μm) —about 1% — such a low content of this fraction was not recorded in other samples. The control soil samples taken on the terrace were light loamy, while the anthill samples were medium loamy, and as well as in the samples of ant nests on the floodplain they showed a reduced content of the fine sand fraction, about 18% compared to 28% in control soil. The content of all other fractions in the anthill sample was slightly higher than in the control soil. At the watershed, the granulometric composition of the control soil and ant nests practically did not differ.

Figure 3 presents the generalized data of particle size analysis of all samples, without considering the relief. Of these, we can conclude that the granulometric composition of ant nests is more variable and that, apparently, in the process of nesting, ants do not show a preference for particles of a certain size. Probably, they can use thinner fractions as cement. If we assume that the ants have any preferences to the size of the soil particles that make up the nest and its structural elements, then these differences should be sought at the level of microaggregates.

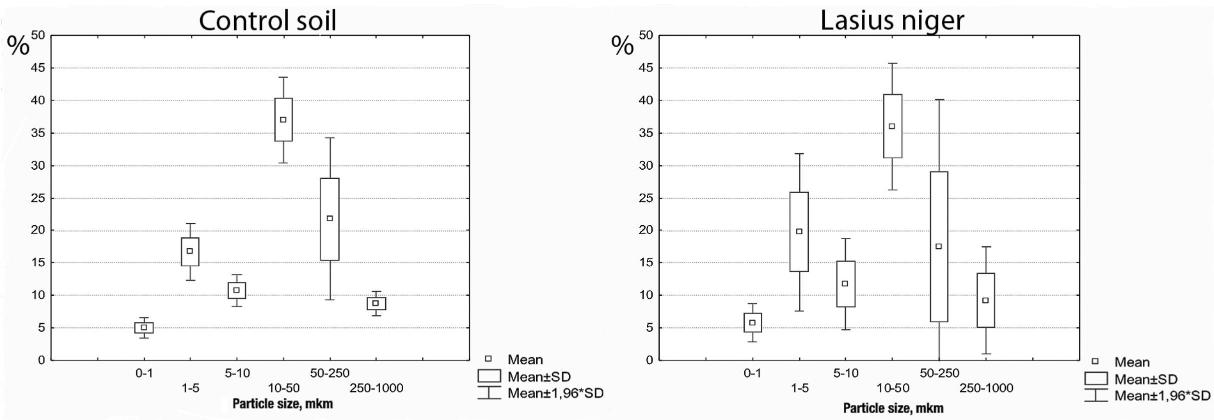

Figure 3. Scale diagram of the particle size distribution of control soils and ant nests.

4. Conclusion

The presented data clearly show that in the process of nesting, ants significantly change the physical indicators of the soil. Most clearly, in our opinion, this is manifested in a change of the hardness of the soil. The differences exceed the difference in the properties of the soils of the zonal series and more. So, the nest building activity of soil-dwelling ants is a significant, but local factor of soil formation, giving it the features of intrazonality. Thus, the soil is saturated with numerous soil individuals (in this case - nests of ants) including the organic and mineral horizons of the host soil and characterized by specific physical, chemical and biological properties. The formation and existence of these individuals is entirely controlled and linked to the vital activity of the ant colony.

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